

# (12) UK Patent Application (19) GB (11) 2 330 096 (13) A

(43) Date of A Publication 14.04.1999

(21) Application No 9722184.0

(22) Date of Filing 22.10.1997

(30) Priority Data

(31) 9721465 (32) 10.10.1997 (33) GB

(71) Applicant(s)

GKN Sankey Limited  
(Incorporated in the United Kingdom)  
PO Box 20, Hadley Castle Works, Hadley, TELFORD,  
Shropshire, TF1 4RE, United Kingdom

(72) Inventor(s)

Peter Amborn  
Simon Jonathan Giles Griffiths

(74) Agent and/or Address for Service

Eric Potter Clarkson  
Park View House, 58 The Ropewalk, NOTTINGHAM,  
NG1 5DD, United Kingdom

(51) INT CL<sup>6</sup>

B21D 39/04 26/02

(52) UK CL (Edition Q )

B3A A122X

B3Q Q1F Q2F2

(56) Documents Cited

US 5564785 A US 5333775 A US 4151632 A

(58) Field of Search

UK CL (Edition Q ) B3A , B3Q

INT CL<sup>6</sup> B21D 26/00 39/00

On line databases WPI, EDOC, JAPIO

(54) Abstract Title

A process for producing a tubular structural element

(57) A process for forming an elongate structural element of desired shape being of large and small cross-sectional dimensions at spaced locations along its length, the process including the steps of :-

(i) selecting a first tube  $T_1$  for forming a first selected length of the element having cross-sectional dimensions within a first range of relatively small cross-sectional dimensions within the hydro-forming-elongation ratio capabilities of the material from which the first tube is formed, said first tube being of a first constant cross-sectional dimension along its length,

(ii) selecting a second tube  $T_2$  for forming a second selected length of the element adjacent to the first length, the second length of the element having cross-sectional dimensions within a second range of relatively large cross-sectional dimensions within the hydro-forming elongation ratio capabilities of the material from which the second tube is formed, said second tube being of a second constant cross-sectional dimension along its length which is different to said first constant cross-sectional dimension,

(iii) joining adjacent ends of said first and second tubes together, and

(iv) performing forming operations on the first and second tubes to produce the desired shape of the element.

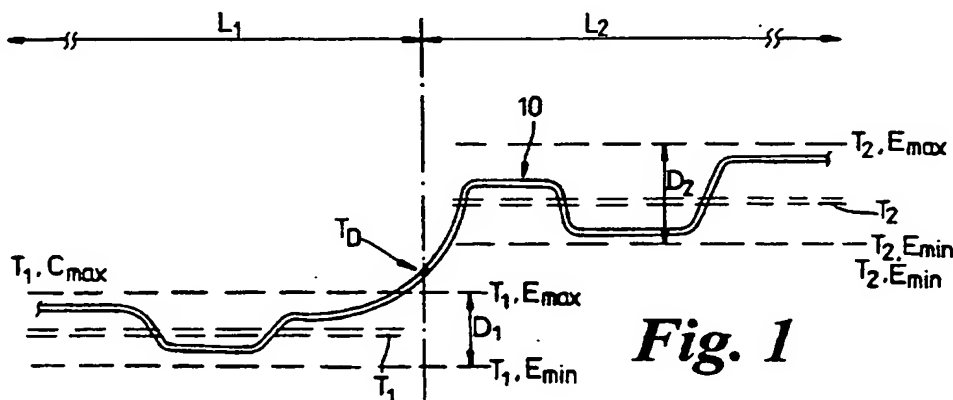


Fig. 1

GB 2 330 096 A

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

This print incorporates corrections made under Section 117(1) of the Patents Act 1977.

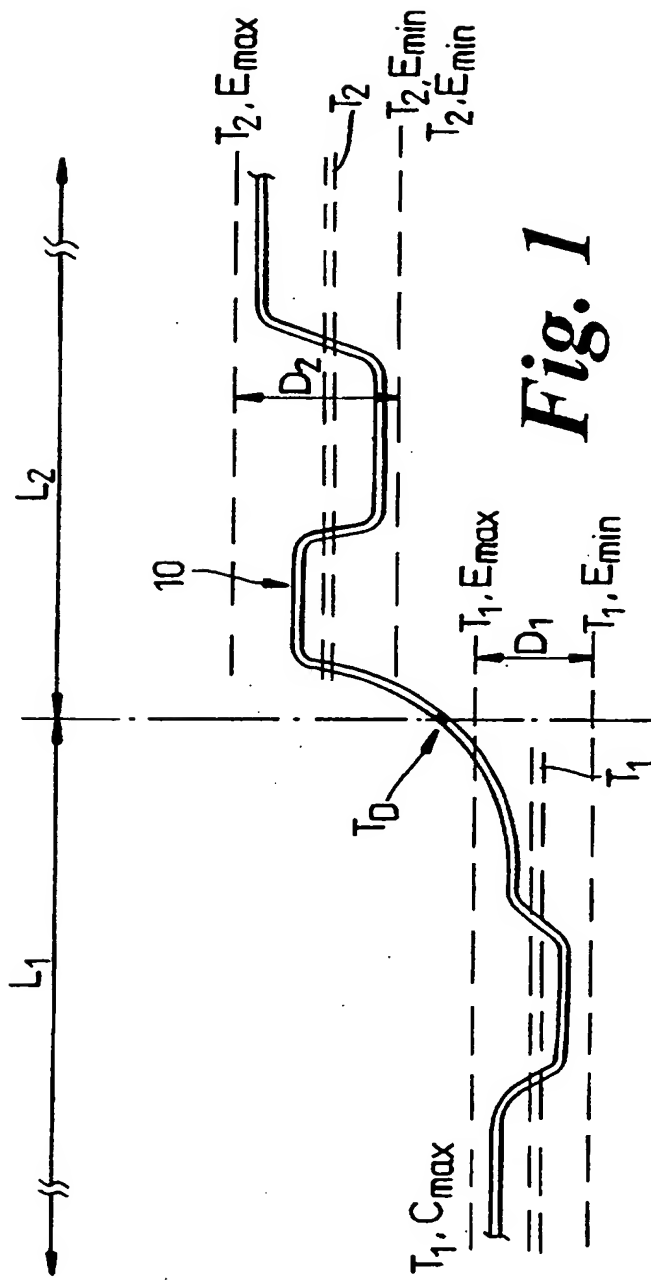


Fig. 1

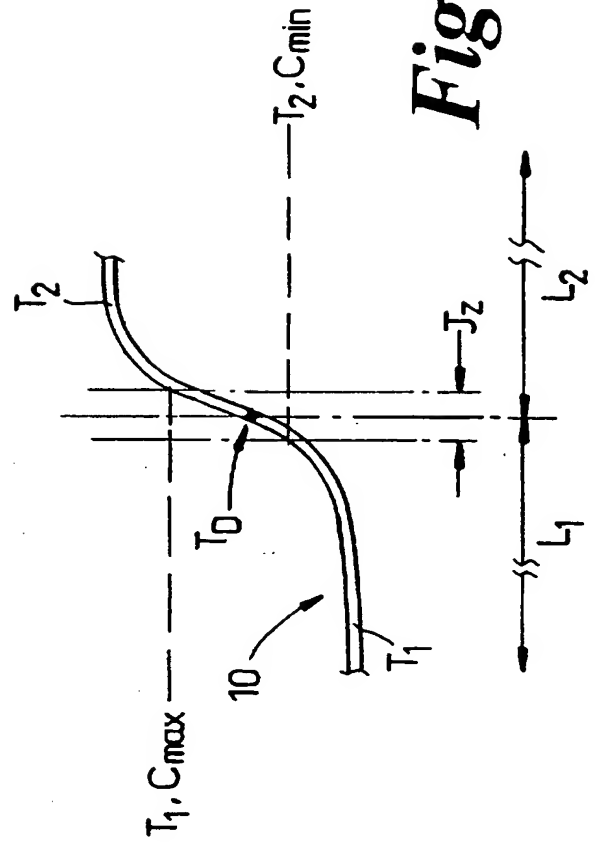


Fig. 2

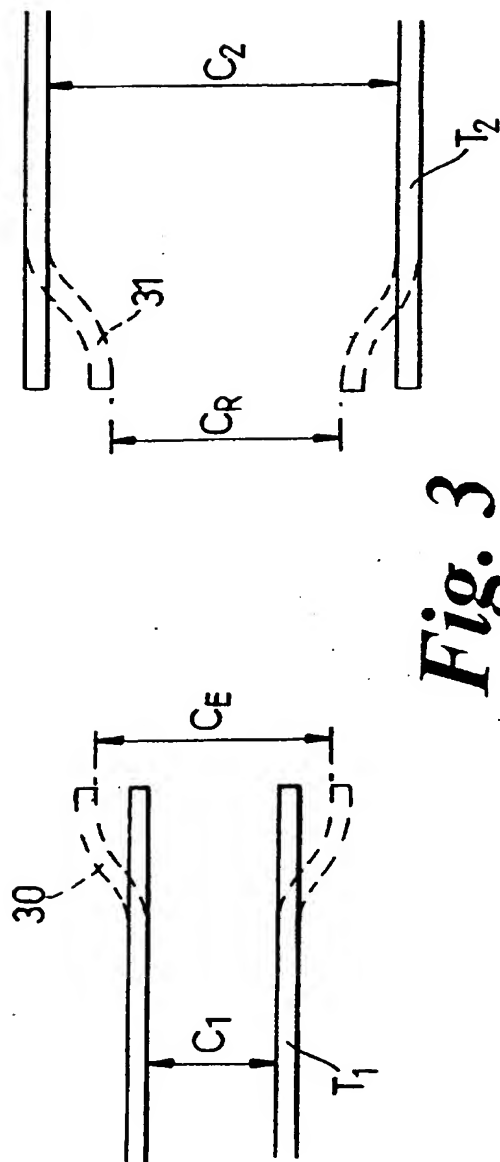


Fig. 3

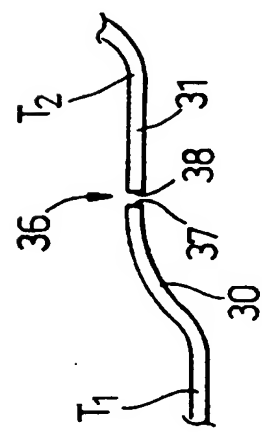


Fig. 4

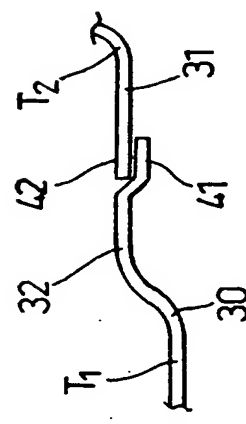


Fig. 5

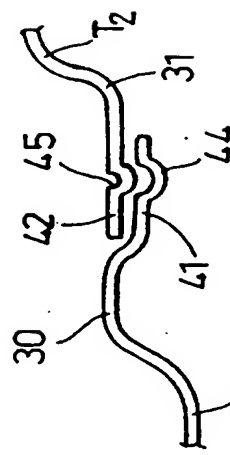
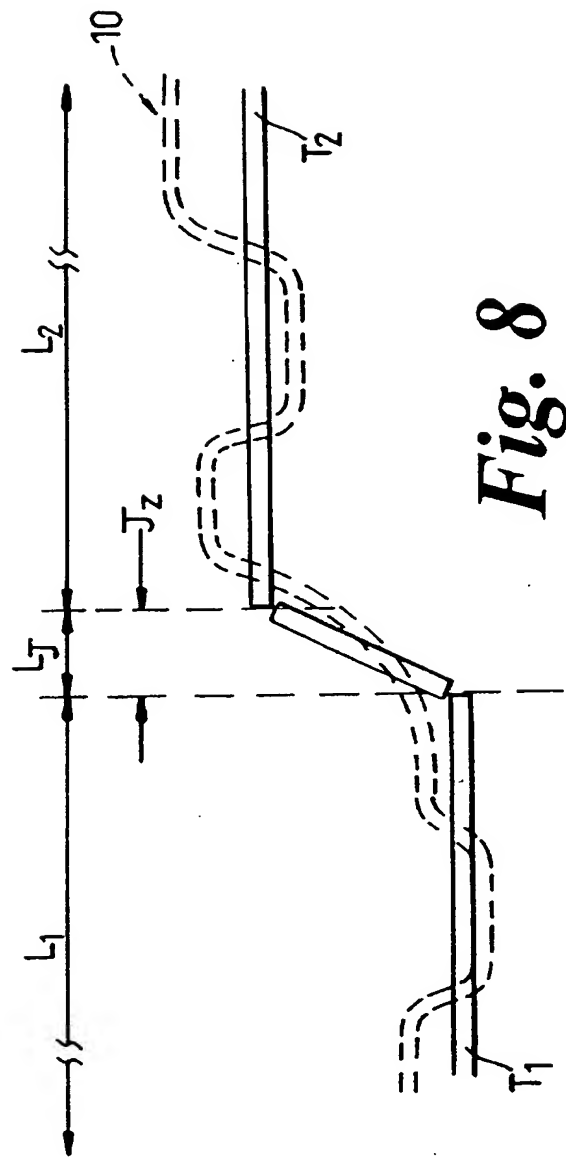
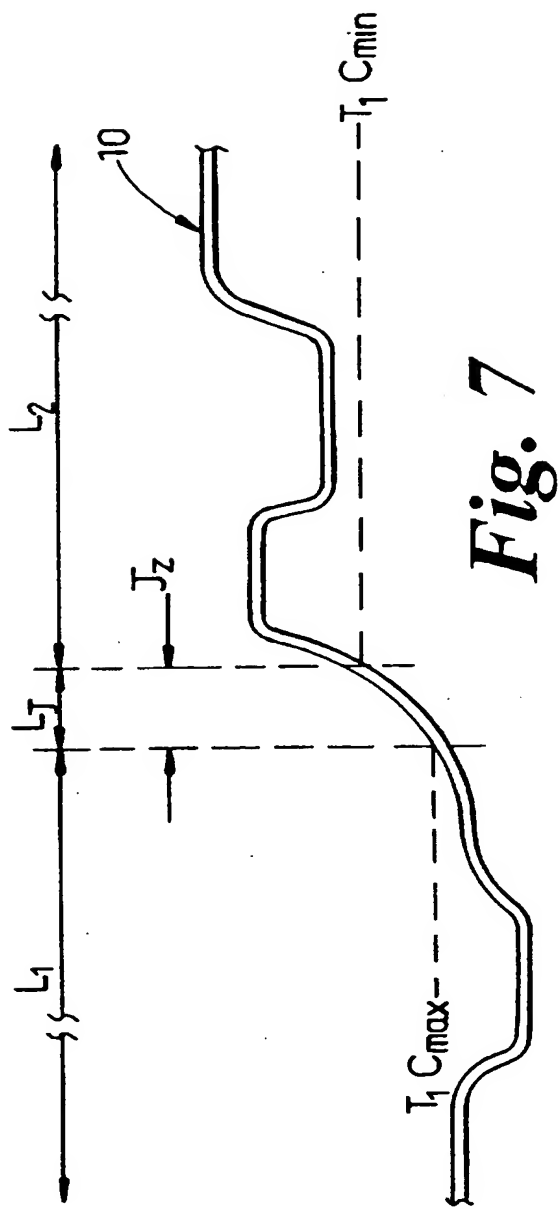


Fig. 6



## A PROCESS FOR PRODUCING A TUBULAR STRUCTURAL ELEMENT

The present invention relates to a process for producing a tubular  
5 structural element, and to a tubular structural element which is  
particularly, but not exclusively, suitable for use in the construction of  
vehicles.

In the construction of vehicles, tubular structural elements are widely used  
10 which are of complex shape and cross-sectional dimensions vary widely  
along their length. Examples of such elements in an automobile are the  
A-pillar, the B-pillar, or the instrumentation panel beam.

These elements are usually formed into final shape from a tube which  
15 prior to the forming process is of constant cross-section. The forming  
process may be cold or warm fluid pressure forming. Forming tubes into  
desired shapes using a fluid medium which is supplied internally of the  
tube under pressure is known. The medium may be small solid balls  
which collectively act as a fluid, or may be a liquid such as a suitable oil  
20 or may be a gas such as air or steam. In this specification the forming  
process which utilises a pressurised fluid medium is referred to as a  
hydro-forming process.

The hydro-forming process is restricted by the hydro-forming-elongation  
25 ratio of the material from which the tube is made and so with a single tube  
it is only possible for the maximum and minimum cross-sectional  
dimensions of the final shape of the element to differ by twice the hydro-  
forming-elongation ratio of the material.

30 In the present specification the term 'hydro-forming-elongation ratio' of

a material is the amount by which the material can be elongated under the conditions of hydro-forming processes.

It is a general aim of the present invention to provide a process for forming, preferably using cold or warm hydro-forming techniques, a tubular structural element having maximum and minimum cross-sectional dimensions which can differ by more than twice the hydro-forming-elongation ratio of the material from which the element is made.

According to one aspect of the present invention there is provided a process for forming an elongate structural element of desired shape being of large and small cross-sectional dimensions at spaced locations along its length, the process including the steps of :-

(i) selecting a first tube for forming a first selected length of the element having cross-sectional dimensions within a first range of relatively small cross-sectional dimensions within the hydro-forming-elongation ratio capabilities of the material from which the first tube is formed, said first tube being of a first constant cross-sectional dimension along its length,

(ii) selecting a second tube for forming a second selected length of the element adjacent to the first length, the second length of the element having cross-sectional dimensions within a second range of relatively large cross-sectional dimensions within the hydro-forming-elongation ratio capabilities of the material from which the second tube is formed, said second tube being of a second constant cross-sectional dimension along its length which is different to said first constant cross-sectional dimension,

(iii) joining adjacent ends of said first and second tubes together, and

(iv) performing forming operations on the first and second tubes to produce the desired shape of the element.

If desired, step (iv) may be performed before step (iii).

Preferably said first and second constant cross-sectional dimensions respectively lie outside said second and first ranges of cross-sectional dimensions, and joining of said first and second tubes includes the steps  
5 of :-

(v) enlarging one end of the first tube to form a first connection formation of greater cross-sectional dimension than said first constant cross-sectional dimension, and/or

10 (vi) reducing one end of the second tube to form a second connection formation of lesser cross-sectional dimension than said second constant cross-sectional dimension,

(vii) joining the first and second connection formations together to join said first and second tubes together.

15

Step (v) and/or step (vi) may be performed using any conventional cold or hot deforming technique, including swaging, drawing or hot or cold hydro-forming.

20 The first and second connection formations may be fixedly joined together by bonding techniques such as welding.

Alternatively or in addition, the first and second connecting formations may be formed so as to have overlapping marginal end portions which are  
25 fixedly secured together by a forming operation which causes the overlapping marginal end portions to be pressed together. Preferably relative axial movement between the marginal portions of the first and second connection portions is controlled as the respective marginal portions are pressed together. In this respect, the overlapping marginal  
30 portions may be adapted by shaping so as to provide a mechanical lock

therebetween resisting relative axial movement between the overlapping marginal portions.

Alternatively, or in addition, friction material may be located between the overlapping marginal portions in order to restrain relative axial movement therebetween.

It will be appreciated that the material of the first tube may be the same or different to the material of the second tube and may be of the same or different wall thickness.

The tubes may be symmetrical or asymmetrical in cross-sectional shape.

In accordance with another aspect of the present invention there is provided a process for forming an elongate structural element of desired shape being of large and small cross-sectional dimensions at spaced locations along its length, the process including the steps of :-

(i) selecting a first tube for forming a first selected length of the element having cross-sectional dimensions within a first range of relatively small cross-sectional dimensions within the hydro-forming-elongation ratio capabilities of the material from which the first tube is formed, said first tube being of a first constant cross-sectional dimension along its length,

(ii) selecting a second tube for forming a second selected length of the element adjacent to the first length, the second length of the element having cross-sectional dimensions within a second range of relatively large cross-sectional dimensions within the hydro-forming-elongation ratio capabilities of the material from which the second tube is formed, said second tube being of a second constant cross-sectional dimension along its length which is different to said first constant cross-sectional dimension,



(iii) selecting an intermediate connection tube having a first end of relatively small cross-sectional dimension and a second end of relatively large cross-sectional dimension;

5 (iv) joining said first and second tubes together by connecting one end of the first tube to the first end of the connection tube and by connecting one end of the second tube to the second end of the connection tube, and

(v) performing forming operations on the first, second and connection tubes to produce the desired shape of the element.

10

Preferably the connection tube is connected to the first and second tubes by welding.

15

Preferably the connection tube progressively increases in cross-sectional dimensions from its first end to its second end at a substantially constant rate along its length. In a preferred embodiment, the connection tube is in the form of a truncated cone.

20

Various aspects of the present invention are hereinafter described, with reference to the accompanying drawings in which:-

Figure 1 is a schematic illustration of a longitudinal portion of a finished tubular structural element according to the present invention;

Figure 2 is a more detailed schematic illustration of the element shown in Figure 1 in the region of jointing between adjacent tubes;

25

Figure 3 is a schematic illustration showing first and second tubes for forming respective first and second lengths of the element in Figure 1;

Figures 4, 5 and 6 schematically illustrate alternative configurations for joining the first and second connection formations,

30

Figure 7 is an illustration similar to Figure 1 showing a different

embodiment,

Figure 8 is an illustration showing tubes prior to formation into the tubular element shown in Figure 7.

- 5 Referring initially to Figure 1 there is shown a longitudinal wall portion of a tubular structural element 10.

The element 10 is divided into longitudinal sections  $L_1$ ,  $L_2$  wherein within section  $L_1$  the cross-sectional dimensions of the element 10 vary within a first range of dimensions  $D_1$  and wherein within section  $L_2$  the cross-sectional dimensions of the element vary within a second range of dimensions  $D_2$ .

15 The element 10 is generally formed from tubes  $T_1$  and  $T_2$  which are joined end to end to form single element 10 which has continuous structural integrity along its length.

The element 10 is formed by deforming the material of the tubes  $T_1$  and  $T_2$  using cold or hot hydro-forming techniques and so relies upon the hydro-forming-elongation ratio capabilities of the materials of tubes  $T_1$  and  $T_2$  under the temperature conditions of the cold or hot hydro-forming process. The maximum and minimum cross-sectional dimensions which tube  $T_1$  is capable of forming under these conditions is illustrated by lines  $T_1$ ,  $E_{max}$  and  $T_1$ ,  $E_{min}$  respectively and for tube  $T_2$  are illustrated by lines  $T_2$ ,  $E_{max}$ , and  $T_2$ ,  $E_{min}$  respectively.

As shown in Figure 1, the tubes  $T_1$  and  $T_2$  are joined at a location  $T_D$  and this location has to be chosen to occur at a longitudinal position along the element 10 whereat the following condition applies, viz the maximum cross-sectional dimension  $T_1$ ,  $C_{max}$  achievable by elongation of tube  $T_1$  (by

any conventional technique) is greater or equal to the minimum cross-sectional dimension  $T_2, C_{\min}$  achievable by elongation of tube  $T_2$  (by any conventional technique).

- 5 In Figure 1,  $T_1, C_{\max}$  is shown as being equal to  $T_2, C_{\min}$ . However, as illustrated diagrammatically in Figure 2, when  $T_1, C_{\max}$  is greater than  $T_2, C_{\min}$ , then the greater the difference between  $T_1, C_{\max}$  and  $T_2, C_{\min}$  the longer the length zone  $J_z$  along which the joint  $T_D$  may be selectively located.

10

Accordingly it is possible by analysing the variation of cross-sectional dimensions along the length of element 10 to identify length sections  $L_1, L_2, \dots$  etc having cross-section dimensions varying within predetermined ranges and to select appropriate lengths of tubes  $T_1, T_2$  etc having  
15 predetermined elongation capabilities for forming corresponding length sections  $L_1, L_2$  etc.

20

In order to form a single element 10 which has structural integrity along its length, it is necessary to join tubes  $T_1, T_2$  end to end in a rigid manner at a location  $T_D$ .

25

In a preferred embodiment, as illustrated in Figure 3, the tube  $T_1$  is of a constant cross-sectional dimension  $C_1$  which is less than the minimum dimension  $T_2, E_{\min}$  of tube  $T_2$  and tube  $T_2$  is of a constant cross-sectional  
dimension  $C_2$  which is greater than the maximum dimension  $T_1, E_{\max}$  of tube  $T_1$ . This is preferred since, in combination, such tubes  $T_1, T_2$  enable a wide variation of cross-sectional dimensions to be achieved viz from the lower limit of  $D_1$  to the upper limit of  $D_2$  as in the case where  $T_1, E_{\max} = T_2, E_{\min}$ .

30

Accordingly, with this arrangement in order to join tubes  $T_1$ ,  $T_2$  together at least one end or preferably both respective ends of the tubes need to be deformed to create first and second connection formations 30, 31 respectively.

5

The connection formation 30 is formed by enlarging the end of tube  $T_1$  to a cross-sectional dimension  $C_E$  which is greater than its constant cross-sectional dimension  $C_1$ .

10

The connection formation 31 is formed by reducing the end of tube  $T_2$  to a cross-sectional dimension  $C_R$  which is less than its constant cross-sectional dimension  $C_2$ .

15

Deformation of tube  $T_1$  and/or tube  $T_2$  in order to form connection formations  $C_1$ ,  $C_2$  respectively may be achieved by any conventional techniques, eg. cold forming such as swaging or hot forging techniques. Accordingly the amount of deformation to achieve  $C_E$  and/or  $C_R$  may be such as to exceed to respective hydro-forming-elongation ratios of tubes  $T_1$ ,  $T_2$  respectively.

20

The cross-sectional dimensions  $C_E$  and  $C_R$  are chosen such that the connection formations 30, 31 may be joined to one another.

25

In this respect,  $C_E$  and  $C_R$  may be the same in order to define a butt joint 36 as illustrated in Figure 3, the respective abutting ends 37, 38 of tubes  $T_1$  and  $T_2$  being bonded together by suitable bonding techniques such as welding or brazing.

30

Alternatively as illustrated in Figures 4 and 5, the connection formations 30, 31 may be formed so as to have overlapping marginal end portions 41,

42 which in effect are telescopically engaged.

Overlapping end portions 41, 42 may provide a dry joint by expansion of the inner portion 41 into pressing contact with the outer portion 42 during the forming process for forming the final shape of the element 10 from tubes  $T_1$ ,  $T_2$ .

Preferably the overlapping portions 41, 42 are controlled during this forming process so as to be restrained from relative axial movement. Accordingly, in the embodiment illustrated in Figure 5, friction material is preferably located inbetween opposed faces of portions 41, 42.

In the embodiment of Figure 6, the opposed faces of the portions 41, 42 are provided with one or more recesses 44 and co-operating ribs 45 respectively which after initial expansion of the inner portion 41 co-operate to form a mechanical lock to restrain relative axial movement. It will be appreciated however that friction material may also be provided between portions 41, 42 in embodiment of Figure 6 if desired.

It is also envisaged that the overlapping portions 41, 42 may be secured together by riveting techniques, such as blind rivets.

In the above example, two tubes  $T_1$ ,  $T_2$  are described for forming a length portion of element 10. It will be appreciated that two tubes  $T_1$ ,  $T_2$  may be sufficient to form the entire length of element 10 or that additional tubes having different hydro-forming-elongation ratios capabilities to tubes  $T_1$ ,  $T_2$  may be incorporated.

In this respect, it will be appreciated that the choice of which tube should be located at a given location along the length of the element 10 can be

influenced by the constant cross-sectional dimension of the tube and the material from which it is made.

For example it is envisaged that tubes of the same or different materials  
5 may be joined end to end. For example, the element 10 may be composed  
of deformed tubes made from steel and aluminium.

The forming process for deforming the tubes  $T_1$ ,  $T_2$  is preferably  
performed after joining of the tubes and is preferably cold or warm hydro-  
10 forming.

It is envisaged that, if desired, one of the tubes  $T_1$ ,  $T_2$  may have a  
constant cross-section dimension  $C_1$ , or  $C_2$  respectively which lies within  
the range of dimensions  $D_1$  or  $D_2$  of the other tube. In such a case it will  
15 be appreciated that the end of only one tube needs to be deformed in order  
to form a connection formation for connection to the end of the other tube.

It is also envisaged that deformation by hydro-forming may be performed  
on one tube only and that the other tube may be of constant cross-section  
20 along its length or deformed by other conventional techniques. If these  
tubes are to be joined as per the Figure 5 and 6 embodiments, then  
overlapping portions 41, 42 are preferably formed by a hydro-forming  
process.

25 It will be appreciated that the tubes  $T_1$ ,  $T_2$  may be of symmetrical or  
asymmetrical cross-sectional shape relative to their longitudinal axis.

It is also to be appreciated that the connection formations 30 and/or 31  
may be formed so as to be symmetrical or asymmetrical relative to the  
30 longitudinal axis of the respective tubes  $T_1$ ,  $T_2$ .

Accordingly, after joining, the tubes  $T_1$ ,  $T_2$  may be co-axial or may have axes off-set to one another.

A further embodiment is illustrated in Figures 7 and 8.

5

As illustrated in Figure 7, the element 10 has two lengths  $L_1$  and  $L_2$  formed from respective tubes  $T_1$  and  $T_2$ . However the tubes  $T_1$  and  $T_2$  do not have the capability of being deformed such that  $T_1 C_{\max} > T_2 C_{\min}$ . Instead, in Figure 7,  $T_1 C_{\max} < T_2 C_{\min}$  and so direct connection between  
10 the ends of tubes  $T_1$  and  $T_2$  is not possible.

To secure tubes  $T_1$  and  $T_2$  together a connection tube  $T_c$  is provided which is located inbetween tubes  $T_1$  and  $T_2$ . The connection tube  $T_c$  has a first axial end 60 of relatively small cross-sectional dimension and a second  
15 axial end 61 of relatively large cross-sectional dimension.

The cross-sectional shape and dimension of the first axial end 60 approximates to that of the end of tube  $T_1$  to which it is connected and similarly the cross-sectional shape and dimension of the second axial end  
20 61 approximates to that of the end of tube  $T_2$  to which it is to be connected. This is schematically illustrated in Figure 8.

The respective ends of tubes  $T_1$ ,  $T_c$  and  $T_2$  are bonded together using conventional bonding techniques such as welding or brazing.

25

After joining of tubes  $T_1$ ,  $T_c$  and  $T_2$ , the connected tubes are deformed by hydro-forming to form element 10.

In the example illustrated in Figures 7 and 8 the axial length  $L_1$  of tube  $T_c$   
30 has a minimum value which is determined by the difference between  $T_1$

$C_{\max}$  and  $T_2 C_{\min}$ . This minimum value is represented in Figures 7 and 8. However, it will be appreciated that length  $L_1$  may be chosen to be longer taking into consideration the amount of deformation required by tubes  $T_1$  and  $T_2$  during the hydro-forming stage.

5

It will also be appreciated that use of a connection tube  $T_c$  is not restricted to the situation where  $T_1 C_{\max} < T_2 C_{\min}$  and that a connection tube  $T_c$  may be utilised in the embodiments described in relation to Figures 1, 2 and 3.

10

It will also be appreciated that any of the tube connection techniques described in relation to Figures 4, 5 or 6 may be used for joining tube  $T_c$  to tube  $T_1$  and/or tube  $T_2$ .

15 The material from which tube  $T_c$  is formed may be the same or different to that used for tubes  $T_1$  or  $T_2$ .

It will be appreciated that the cross-sectional shape of the first and second ends 60, 61 respectively of tube  $T_c$  correspond to the shape of the ends of tubes  $T_1$  and  $T_2$  to which they are connected. However, the cross-sectional shape of the tube  $T_c$  intermediate its first and second ends 60, 61 may be of any appropriate shape bearing in mind the required cross-sectional shape of element 10.

25 Usually connection tube  $T_c$  will be of constant cross-sectional shape along its length and will progressively increase in cross-sectional dimension from end 60 to end 61. Thus, the tube  $T_c$  will usually be in the form of a truncated cone.



CLAIMS

1. A process for forming an elongate structural element of desired shape being of large and small cross-sectional dimensions at spaced  
5 locations along its length, the process including the steps of :-

(i) selecting a first tube for forming a first selected length of the element having cross-sectional dimensions within a first range of relatively small cross-sectional dimensions within the hydro-forming-elongation ratio capabilities of the material from which the first tube is  
10 formed, said first tube being of a first constant cross-sectional dimension along its length,

(ii) selecting a second tube for forming a second selected length of the element adjacent to the first length, the second length of the element having cross-sectional dimensions within a second range of relatively large  
15 cross-sectional dimensions within the hydro-forming elongation ratio capabilities of the material from which the second tube is formed, said second tube being of a second constant cross-sectional dimension along its length which is different to said first constant cross-sectional dimension,

(iii) joining adjacent ends of said first and second tubes together,  
20 and

(iv) performing forming operations on the first and second tubes to produce the desired shape of the element.

2. A process according to Claim 1 wherein step (iv) is performed  
25 before step (iii).

3. A process according to Claim 1 or 2 wherein said first and second constant cross-sectional dimensions respectively lie outside said second and first ranges of cross-sectional dimensions, and joining of said first and  
30 second tubes includes the steps of :-

(v) enlarging one end of the first tube to form a first connection formation of greater cross-sectional dimension than said first constant cross-sectional dimension, and/or

5 (vi) reducing one end of the second tube to form a second connection formation of lesser cross-sectional dimension than said second constant cross-sectional dimension,

(vii) joining the first and second connection formations together to join said first and second tubes together.

10 4. A process according to any of Claims 1 to 3 wherein in step (iv) at least one of the tubes is deformed using hydro-forming techniques.

5. A process according to Claim 1 wherein the ends of the first and second tubes are joined together by an intermediate connection tube.

15

6. A process according to any preceding claim wherein the first and second tubes are formed from the same material.

7. A process according to any of Claims 1 to 5 wherein the first and  
20 second tubes are formed from different materials.

8. A process according to any preceding claim wherein step (iii) includes forming overlapping end portions which are fixedly secured together.

25

9. A process according to Claim 8 wherein the overlapping end portions are secured together by welding.

10. A process according to Claim 8 wherein the overlapping end  
30 portions are secured together by mechanical fixing.

11. A process according to Claim 8 wherein the overlapping end portions are secured together by bonding.

12. A process according to Claim 9, 10 or 11 wherein a layer of friction material is located inbetween said overlapping end portions.

13. A process for forming an elongate structural element of desired shape being of large and small cross-sectional dimensions at spaced locations along its length, the process including the steps of :-

10 (i) selecting a first tube for forming a first selected length of the element having cross-sectional dimensions within a first range of relatively small cross-sectional dimensions within the hydro-forming-elongation ratio capabilities of the material from which the first tube is formed, said first tube being of a first constant cross-sectional dimension  
15 along its length,

(ii) selecting a second tube for forming a second selected length of the element adjacent to the first length, the second length of the element having cross-sectional dimensions within a second range of relatively large cross-sectional dimensions within the hydro-forming-elongation ratio capabilities of the material from which the second tube is formed, said  
20 second tube being of a second constant cross-sectional dimension along its length which is different to said first constant cross-sectional dimension,

(iii) selecting an intermediate connection tube having a first end of relatively small cross-sectional dimension and a second end of relatively  
25 large cross-sectional dimension;

(iv) joining said first and second tubes together by connecting one end of the first tube to the first end of the connection tube and by connecting one end of the second tube to the second end of the connection tube, and

(v) performing forming operations on the first, second and connection tubes to produce the desired shape of the element.

14. A process for forming an elongate structural element substantially  
5 as herein described with reference to the accompanying drawings.

15. A tubular structural element comprising at least two tubes joined end to end, at least one of the tubes being shaped by a hydro-forming process.



Application No: GB 9722184.0  
Claims searched: All claims

Examiner: A.R. Martin  
Date of search: 30 December 1997

**Patents Act 1977**  
**Search Report under Section 17**

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK CI (Ed.O): B3A,B3Q

Int CI (Ed.6): B21D 39/00,26/00

Other: On line databases WPI,EDOC,JAPIO

**Documents considered to be relevant:**

Category	Identity of document and relevant passage	Relevant to claims
X	US5333775 A General Motors see claim 1	Claims 1 and 13 at least
X	US5564785 A Atoma see column 5 lines 40-50	"
X	US4151632 A Arvin see claim 5	"

X Document indicating lack of novelty or inventive step  
Y Document indicating lack of inventive step if combined with one or more other documents of same category.  
& Member of the same patent family

A Document indicating technological background and/or state of the art.  
P Document published on or after the declared priority date but before the filing date of this invention.  
E Patent document published on or after, but with priority date earlier than, the filing date of this application.